may be fabricated in two halves, on two separate substrates. Alternatively a first substrate may be processed to define the necessary features required for formation of the ion guide, then separated into two or more portions which are sandwiched together to form the final structure. In each arrangement, each substrate carries a set of features which cooperate when sandwiched, with corresponding features on the second mating substrate to form a closed pupil. Desirably such a pupil is fabricated by forming on an upper surface of each of the features a groove. When two opposing grooves are brought together they form a contiguous surface defining an aperture within the features which forms the requisite closed pupils. The features on the first and second substrates desirably form a set of diaphragm electrodes. Such ion guides may be fabricated by etching and wafer bonding and the invention also teaches methods for varying the size of the electrode pupils along the ion path and for varying the direction of the ion path.

[0015] The construction of the microengineered stacked ring ion guide fabricated in accordance with the teaching of the invention may be better understood with reference to FIGS. **2**-**7**, which are, it will be appreciated, provided to assist in an understanding of the teaching of the invention and are not to be construed as limiting in any fashion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. **1** shows a stacked ring RF ion guide, according to the prior art.

[0017] FIG. **2** shows in cross-section different groove shapes (rectangular, truncated triangular and semicircular) fabricated in a layer of material on a substrate, which may be useful according to the present invention.

[0018] FIG. **3** shows in cross-section a formation of a diaphragm electrode with a closed pupil from two substrates carrying grooved proud features, according to the present invention.

[0019] FIG. **4** shows in plan a layout of a single substrate of a stacked ring ion guide with separated electrodes, according to the present invention.

[0020] FIG. **5** shows in plan and cross-section a suitable layout and assembly of a complete stacked ring ion guide with bus bars interconnecting the electrodes, according to the present invention.

[0021] FIG. **6** shows in plan layouts of meandered and tapered ion guides, provided according to the present invention.

[0022] FIG. **7** shows a microengineered ion guide located on a common substrate with a microengineered electrostatic quadrupole mass filter, according to the teaching of the present invention.

DETAILED DESCRIPTION

[0023] An example of a conventional ion guide has been described with reference to FIG. **1**. The inventors of the present invention have realized that below a certain size scale, typically a few hundred microns in feature size, conventional machining methods such as milling, slotting and drilling become inappropriate for fabricating complex structures. Instead, microengineering or microfabrication methods are employed. These processes are known elsewhere as techniques that are generally carried out on planar substrates, which are often silicon or multilayers containing silicon or other semiconducting materials. Within the context of the following description techniques including patterning methods such as photolithography, etching methods such as wet chemical etching, crystal plane etching, plasma etching, deep reactive ion etching and powder blasting, coating methods such as evaporation and sputtering, and wafer bonding methods such as thermocompression bonding, anodic bonding and soldering will be useful. These methods are well known to those skilled in the art and require no explanation here.

[0024] It will be understood that patterning and etching methods act on an exposed surface and as such it is difficult to form closed pupils in a set of diaphragm electrodes lying perpendicular to the surface. The present inventors have realized that these difficulties can be overcome if the structure is fabricated in two halves, which are then assembled by stacking or bringing together to form a sandwich structure, with the electrodes provided in an inner portion of the sandwich. It is then possible to use planar processing to form groove shaped features on each half, as shown in FIG. **2**, which are subsequently combined together to form complete apertures.

[0025] For example, following the teaching of the invention, it is possible to form a rectangular groove **201** in a layer **202** lying on a substrate **203**. If (for example) the material of the layer is silicon, a suitable groove may be formed through deep reactive ion etching, using a surface mask with a strip-shaped opening. Deep reactive ion etching is a method of structuring silicon that uses alternating cycles of etching and passivation in a high density inductively coupled plasma to provide highly anisotropic etching (Hynes 1999).

[0026] Similarly, a groove **204** bounded by sloping walls may be formed by wet chemical etching down (111) crystal planes in (100) oriented silicon (Lee 1969). If such a groove is etched to completion, its cross-section will be triangular. However, if it is not etched to completion (as shown here), it will be truncated, with a (100) plane lying at its base.

[0027] Similarly, an approximately semicircular groove **205** may be formed by an isotropic plasma etch, which may be provided by omitting the passivation cycles in a deep reactive ion etching process. Similar grooves may be formed using abrasive powder blasting. More restrictively, straight grooves may be formed using a dicing saw with a profiled blade. The layer **202** is upstanding from the surface **203** of the substrate and the groove is formed in an upper surface of the layer **202**. The layer may be considered a feature that is standing proud of the substrate and having a depression or recess, the groove, formed in an upper surface thereof.

[0028] If the required electrode pupil is too large, groove depths greater than the thickness of the single layer derived from (for example) a standard silicon wafer may be required. In this case, the groove may be formed in a multilayer, which may itself be formed by stacking and bonding more than one layer of material.

[0029] Once patterned, two such grooved structures **301***a* and **301***b* may be combined together with their etched surfaces aligned and abutted to form a structure **302** as shown in FIG. **3**. It will be appreciated that this arrangement will create a substantially closed channel **303** lying in the plane of the substrates. The channel **303** is formed from the mating of the first **301***a* and second **301***b* substrates in a manner that provides for an overlap of the previously etched groove feature in each of the substrates. While the groove feature represents a depression in the upper surface of the feature, it has a surface which when two features are brought together in a sandwich structure—such as described in FIG. **3**—the surfaces of the opposing grooves form a contiguous surface defining the